Nonprovisional Utility Patent Application of

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For

METHOD AND APPARATUS FOR A WASTE HEAT RECYCLING THERMAL POWER PLANT

Title of Invention

Method and apparatus for a waste heat recycling thermal power plant.

Cross-Reference to Related Applications

Not applicable.

Statement Regarding Federally Sponsored Research or Development

Not applicable.

Reference to a Sequence Listing, a Table, or a Computer Program Listing Compact Disc Appendix

Not applicable.

Background of the Invention

1. Field of the Invention

This invention relates to the field of thermal power plants, specifically of the type that recycle a significant portion of the heat that is normally rejected to the environment by "conventional" thermal power plants.

2. Description of the Prior Art

A search of the prior art reveals numerous inventions that attempt to improve the efficiency of various types (e.g., Rankine cycle, Stirling cycle, Brayton cycle, Otto cycle, Diesel cycle, Seebeck cycle, etc.) of heat engines and the thermal power plants in which they are contained.

In 1824, Nicolas Leonard "Sadi" Carnot, a French engineer and founder of the discipline now known as "Thermodynamics," published his treatise (*Reflexions sur la puissance motrice du feu et sur les machines propres a developper cette puissance)* on

the nature of heat engines. The relevant finding of this paper was that all heat engines, in order to function, first receive heat from a "high-temperature" heat source, and then must reject heat (i.e., unused heat, a.k.a. waste heat) to a "low-temperature" heat sink. He also gave us what is now known as the "Carnot Efficiency," which states that the efficiency of a heat engine is improved as the temperature differential between the heat source and the heat sink is increased. In the decades that followed, others expanded upon and clarified our understanding of the nature of heat, and how best to employ it in heat engines. Most notable among them was an engineering professor from Scotland named William J. M. Rankine, who in 1859, published his treatise (*Manual of the Steam Engine and Other Prime Movers)* relating to heat engines, wherein he described what is now known as the "Rankine cycle." Later, still others expanded upon the ideas postulated by Prof. Rankine, a process that continues to the present day.

The Rankine cycle itself is inherently inefficient, yet it has attributes, which have caused it to become one of the leading forms of heat engine cycles employed today. First, the Rankine cycle is well understood by the designers and users of power generation equipment. Second, the Rankine cycle lends itself well to the employment of very large and therefore very cost-effective components. Third, with the exception of "hydro-power" nothing can produce electrical power less expensively than a modern electrical power generating station employing a "modified" Rankine cycle.

The latest attempts to improve upon the Rankine cycle employ various forms of "co-generation;" i.e., they attempt to convert a portion of the waste heat rejected by a "host" heat engine into additional electrical power, industrial process heating, and/or air conditioning capacity. The latter two approaches, while beneficial are not very practical,

for it is a rare or non-existent industrial process that would require all of the waste heat being liberated by the "host" heat engine. Similarly, the air conditioning capacity approach, while quite ingenious, has two burdens hindering its widespread use, first the "host" heat engine needs to be located near the facility to be cooled, and second, air conditioning is not a "stable" demand (i.e., high demand in the summer, and low demand in the winter). Which leaves the additional electrical power approach as the only economically viable method for improving the efficiency of thermal power plants.

There exists a class of heat engines known as "Bottoming Cycle Heat Engines," many of which include components referred to as "Heat Recovery Steam Generators" or HRSG's. Essentially, their designers have placed a second Rankine cycle heat engine in the waste heat stream of the "host" heat engine, and while it is the "environmentally friendly" thing to do, financially it is not very attractive. This approach is costly and does not provide the kind of returns that most electric utility shareholders are looking for on the bottom line of their financial statements.

One of the principal reasons for the resistance to these devices is that they involve extensive and therefore expensive redesigns of existing facilities; as a result they are not being used to rehabilitate older power plants. New facilities, currently under construction, are just now starting to incorporate some of these design elements, yet the larger opportunity is to retrofit the worldwide base of currently operating electrical power generating facilities. To do this, a design approach that accomplishes the following key points must be employed: the design must be environmentally friendly, the design must not require expensive changes to the "host" facility, the design must be reliable, and the design must produce an acceptable financial return. Such a design will meet with

success, to date, not a single example of the prior art has satisfied all of these requirements.

Brief Summary of the Invention

1. Overview

In accordance with the present invention a waste heat recycling thermal power plant **1000** comprises a multitude of interacting volatile working fluid(s) circuits that generate a thermal potential between itself and an employable external heat source, extracting useable heat from that heat source (to replace the heat converted to work or otherwise lost from the system), generating a super-ambient temperature heat source and a sub-ambient temperature heat sink, whose thermal potential is capable of providing a useable heat flow to fuel its incorporated heat engine, recycling collected system thermal losses and much of the useable heat flow that is rejected by its incorporated heat engine to its super-ambient temperature heat source, and the resultant mechanical power output produced by its incorporated heat engine is employed to drive a mechanical load (e.g., gearbox, electrical generator, propeller shaft, etc.).

2. Objects & Advantages

Accordingly, several objects and advantages of the present invention are:

(a) to provide a thermal power plant which can capture and reuse most of the

waste heat that its own operation liberates;

(b) to provide a thermal power plant which can extract useable heat from the environment;

(c) to provide a thermal power plant which can extract useable heat from a "low-temperature" heat source;

(d) to provide a thermal power plant which can extract useable heat utilizing a small thermal potential;

(e) to provide a thermal power plant, which can extract useable heat from the waste heat that is rejected by a "host" heat engine;

(f) to provide a thermal power plant which can create a thermal potential between itself and an employable external heat source;

(g) to provide a thermal power plant which having created a thermal potential between itself and an employable external heat source, can utilize the heat extracted from that external heat source to fuel its own operation;

(h) to provide a thermal power plant which can concentrate the extracted heat to generate a super-ambient temperature heat source to provide a useable heat flow to its incorporated heat engine;

(i) to provide a thermal power plant which can generate a sub-ambient pressure region sufficient to evaporate a portion of its working fluid liquid flow at a sub-ambient temperature, thus creating a sub-ambient temperature heat sink for its incorporated heat engine;

(j) to provide a thermal power plant which can supply a useable heat flow

between its super-ambient temperature heat source and its sub-ambient temperature heat sink, sufficient to fuel its incorporated heat engine;

(k) to provide a thermal power plant which can produce mechanical power in excess of its own operational requirements, sufficient to drive an electrical generator;

(l) to provide a thermal power plant which can produce electrical power in excess of its own operational requirements, sufficient to provide electrical power to the local electrical power distribution grid;

(m) to provide a thermal power plant which can improve the thermal efficiency of the "host" heat engine by lowering the temperature of the host's heat sink;

(n) to provide a thermal power plant which can improve the fuel efficiency of the "host" heat engine by allowing the "host" to operate at a lower power level while still meeting the electrical demand;

(o) to provide a thermal power plant which can reduce the amount of chemical pollution released to the environment by allowing the "host" heat engine, or an allied heat engine, to operate at a lower power level while still meeting the electrical demand; and

(p) to provide a thermal power plant which can increase the output capacity of the "host" engine by adding its electrical output to that of the host's electrical output.

Further objects and advantages are to provide: a thermal power plant that is environmentally friendly, one that will not require expensive modifications to the "host" facility, one that will operate reliably over its operational life-span, and one that will produce an acceptable financial return on its owner's investment. Still further objects and advantages will become apparent from a consideration of the ensuing description and drawings.

Brief Description of the Drawings

Fig 1 shows the main embodiment of the waste heat recycling thermal power plant.

Fig 2 shows an alternative embodiment of the waste heat recycling thermal power plant (which details a different arrangement of components within the suction flow circuit).

Detailed Description

1. Main Embodiment – Physical Layout

A waste heat recycling thermal power plant **1000** consists primarily of two conjoined circuits, a motive flow circuit **1100** and a suction flow circuit **1200** of a volatile working fluid (the conjoined portions of motive flow circuit **1100** and suction flow circuit **1200** are identified as a conjoined flow circuit **1300**). Additionally, waste heat recycling thermal power plant **1000** includes an incorporated heat engine flow circuit **1400** connected to a mechanical output device **1500**, a heat recovery flow circuit **1600** (optional), a heat source flow circuit **1700**, and the subcomponents contained therein. These circuits and their subcomponents are described below; the interconnecting piping/ducting is described only where necessary to add clarity to the description.

Motive flow circuit **1100** which originates at a cfd flow separation chamber **1340-30**, and successively flows through: a cfd motive flow discharge **1340-40**, an mfc fluid transfer device **1120**, an mfc fluid filtering device **1130** (optional), an mfc fluid flow

regulating device **1140**, and discharges to conjoined flow circuit **1300** via a cfc sub-ambient pressure generating device **1320**, which completes the circuit.

Suction flow circuit **1200** which originates at cfd flow separation chamber **1340-30**, and successively flows through: a cfd suction flow discharge **1340-50**, an sfc fluid flow regulating device **1220**, an sfc sfc-hsfc heat recycling heat transfer device **1230**, an sfc shrd-ssths fluid transfer device **1240** [which contains: an ssftd shrd hsfc-sfc evaporative heat transfer device excess fluid discharge **1240-20**, an ssftd cssd overpressure relief device working fluid discharge **1240-30**, and an ssftd ihefc-sfc evaporative heat transfer device working fluid discharge **1240-40**], an sfc sub-ambient temperature heat sink **1250** [which contains: an ssths ihefc-sfc evaporative heat transfer device **1250-20**, an ssths liquid/vapor separation device **1250-30** (optional), an ssths ihefc-sfc evaporative heat transfer device pressure regulating device **1250-40**], an shrd hsfc-sfc evaporative heat transfer device ssths vapor supply device **1260**, an shrd hsfc-sfc evaporative heat transfer device liquid supply device **1270**, an sfc heat replenishment device **1280** [which contains: an shrd hsfc-sfc evaporative heat transfer device **1280-20**, an shrd liquid/vapor separation device **1280-30** (optional), an shrd hsfc-sfc super heat heat transfer device **1280-40** (optional), and an shrd hsfc-sfc evaporative heat transfer device pressure regulating device **1280-50**], and discharges to conjoined flow circuit **1300** via cfc sub-ambient pressure generating device **1320**, which completes the circuit.

Conjoined flow circuit **1300** which originates at a cspgd suction chamber **1320-40**, and successively flows through: a cspgd conjoined flow discharge **1320-50**, a cfc super-ambient temperature heat source **1330** [which contains: a csths cfc-ihefc heat transfer device **1330-20** [which contains: a cchtd super heat heat transfer device **1330-**

20A (optional), a cchtd latent heat heat transfer device **1330-20B**, a cchtd feed heat heat transfer device **1330-20C** (optional)]], a cfc flow divider **1340** [which contains: a cfd conjoined flow discharge **1340-20**, cfd flow separation chamber **1340-30**, cfd motive flow discharge **1340-40**, cfd suction flow discharge **1340-50**, and a cfd fluid import/export device **1340-60**], a cfc safety/service device **1350** [which contains: a cssd fluid thermal expansion device **1350-20**, a cssd overpressure relief device **1350-30**, and a cssd venting/servicing port **1350-40**], and discharges to motive flow circuit **1100** and suction flow circuit **1200** via cfc flow divider **1350**, which completes the circuit.

Incorporated heat engine flow circuit **1400** which originates at the inlet of an ihefc fluid transfer device **1420** (optional, not required if utilizing gravity-induced circulation), and successively flows through: ihefc fluid transfer device **1420** (optional), an ihefc super-ambient temperature heat source **1430** [which contains: an isths cfc-ihefc heat transfer device **1430-20** [which contains: an ichtd feed heat heat transfer device **1430-20A** (optional), an ichtd ihefc starting device **1430-20B** (optional), an ichtd latent heat heat transfer device **1430-20C**, an ichtd liquid/vapor separation device **1430-20D** (optional), and an ichtd super heat heat transfer device **1430-20E** (optional)]], an ihefc vapor export device **1440** [which contains: an ived ihefc working fluid discharge **1440-20**, an ived flow separation chamber **1440-30**, an ived overpressure relief device working fluid discharge **1440-40**, an ived ipedlc working fluid discharge **1440-50**], an ihefc fluid flow regulating device **1450**, an ihefc pressure expansion device **1460** (e.g., Rankine cycle vapor turbine), an ihefc sub-ambient temperature heat sink **1470** [which contains: an isths ihefc-sfc condensing heat transfer device **1470-20**, and an isths venting/servicing port **1470-30**], which completes the circuit.

An ihefc pressure expansion device lubrication circuit **1480** (optional) augments the incorporated heat engine flow circuit **1400**. Ihefc pressure expansion device lubrication circuit **1480** [optional, which contains: an ipedlc pressure regulating device **1480-20**, an ipedlc vapor bearing device **1480-30**, and an ipedlc vapor flow regulating device **1480-40**], bypasses around the ihefc fluid flow regulating device **1450** and the ihefc pressure expansion device **1460**, via an ihefc vapor export device **1440** and an ihefc fluid return device **1490** [which contains: an ifrd ihefc overpressure relief device working fluid discharge **1490-20**, an ifrd ipedlc working fluid discharge **1490-30**, an ifrd flow collecting chamber **1490-40**, and an ifrd isths ihefc-sfc condensing heat transfer device working fluid discharge **1490-50**]. In addition, an ihefc overpressure relief device **1485** is interposed between the ihefc vapor export device **1440** and the ihefc fluid return device **1490**.

Mechanical output device **1500** is connected to incorporated heat engine flow circuit **1400**. Specifically, a mod driven mechanical device **1520** (e.g., gearbox, generator, propeller shaft, etc.) is connected to incorporated heat engine flow circuit **1400** via a mod hermetic power coupling device **1510A** (omit if **1510B** is utilized) or a mod intermediate drive shaft with shaft sealing device **1510B** (omit if **1510A** is utilized), which completes the device.

Heat recovery flow circuit **1600** (optional) originates at the inlet of an hrfc ventilation motive device **1620**, and successively flows through: hrfc ventilation motive device **1620**, an hrfc machinery space **1630** [which contains: an hms exposed surfaces **1630-20** (i.e., floor, walls, ceiling, equipment, piping, etc.), and an hms space overpressure relief device **1630-30** (discharges to the environment)], an hms cooling

distribution device **1640** [optional, which includes: an hcdd working fluid discharge **1640-20**, an hcdd distribution device **1640-30(x)** (one for each unit that requires cooling, "x" – the designation changes for each unit), an hcdd cooled machinery unit **1640-40(x)** ("x" – the designation changes for each unit), and an hcdd cooling exhaust collection device **1640-50(x)** ("x" – designation changes for each unit)], and an hrfc heat recycling heat transfer device **1650** [which contains: an hhrhtd hrfc-hsfc heat recycling evaporative heat transfer device **1650-20**], which completes the circuit.

Heat source flow circuit **1700** originates at the inlet of an hsfc fluid transfer device **1720** (optional, not required if utilizing gravity-induced circulation), and successively flows through: hsfc fluid transfer device **1720** (optional), an hsfc fluid filtering device **1730** (optional), an hsfc fluid import/export device **1740**, an hsfc safety/service device **1750** [which contains: an hssm thermal expansion device **1750-20**, an hssm overpressure relief device **1750-30**, and an hssm venting/servicing port **1750-40**], an hsfc heat source heat transfer device **1760**, an hsfc sfc-hsfc heat recycling heat transfer device **1770**, an hsfc hrfc-hsfc heat recycling condensing heat transfer device **1780**, an hsfc hsfc-sfc super heat heat transfer device **1785** (optional), an hsfc hsfc-sfc evaporative heat transfer device **1790**, and an hsfc hsfc-sfc heat transfer device working fluid discharge temperature regulating device **1795**, which completes the circuit.

In addition, the circuits are constructed of materials suitable for containing the working fluid in each circuit (i.e., chemically compatible, and capable of withstanding the operating conditions imposed by the operation of waste heat recycling thermal power plant **1000**).

Note: Other types of heat engines may be utilized in lieu of the example Rankine cycle vapor turbine unit described above (e.g., Stirling cycle engine, Seebeck cycle thermoelectric generator, etc.). Any heat engine, which is capable of employing the developed thermal potential, may be interposed between cfc super-ambient temperature heat source **1330** and sfc sub-ambient temperature heat sink **1250**. Depending upon the characteristics of the alternative heat engine, and the working fluid(s) utilized, configuration changes may be required (i.e., the routing of conjoined flow circuit **1300** through cfc super-ambient temperature heat source **1330** and suction flow circuit **1200** through sfc sub-ambient heat sink **1250** may need to be altered). In the forgoing, "ambient" refers to the conditions (in terms of absolute pressure and absolute temperature) at cfd flow separation chamber **1340-30**, this reference point, depending upon the characteristics of the working fluid utilized in conjoined flow circuit **1300**, could differ substantially from standard atmospheric conditions (i.e., 14.696 psia and 536.67 deg-R).

2. Main Embodiment - Operation

Every heat engine requires a source of heat to operate, typically it is a hydrocarbon-based fuel that is burned in order to release the energy stored in the substance's inter-atomic chemical bonds. Depending upon the type of heat engine in question, it is normal for a large portion of the heat provided to such engines to be rejected to the environment (i.e., wasted, having performed no useful work). This has been the state of the art since the first recorded example of a heat engine (in the first

century AD, Hero of Alexandria, Egypt is said to have described his Aeolipile, a rudimentary steam turbine). To be sure, the state of the art has improved much over the intervening centuries, yet it remains an unbreakable rule (i.e., the Second Law of Thermodynamics) that all heat engines must reject heat in order to function, and waste heat recycling thermal power plant **1000** is no different in this regard. What is different is the proportion of heat rejected, and the methodology employed to conserve and reuse most of the heat that is rejected in a typical heat engine.

Waste heat recycling thermal power plant **1000** utilizes the interaction of motive flow circuit **1100**, suction flow circuit **1200**, conjoined flow circuit **1300**, incorporated heat engine flow circuit **1400**, mechanical output device **1500**, heat recovery flow circuit **1600** (optional), and heat source flow circuit **1700** to capture and reuse most of the waste heat that its own operation liberates. What follows is an examination of those interactions.

Heat source flow circuit **1700** performs four essential functions in the operation of waste heat recycling thermal power plant **1000**. First, it acquires make-up heat (i.e., replacing the heat that is converted to work or lost from the system) from the heat source (e.g., geothermal pool, solar collector, river, industrial process cooling water, etc.) via hsfc heat source heat transfer device **1760**. Second, it receives recyclable heat (i.e., heat that is wasted in a typical heat engine) from suction flow circuit **1200** via hsfc sfc-hsfc heat recycling heat transfer device **1770**, and the heat recovery flow circuit **1600** (optional) via hfsc hrfc-hsfc heat recycling condensing heat transfer device **1780** (optional). Third, it transports this heat (make-up and recycled) to hsfc hfsc-sfc super heat heat transfer device **1785** (optional) and hsfc hfsc-sfc evaporative heat transfer

device **1790**. Fourth, it provides "chilled" working fluid to hsfc heat source heat transfer device **1760**.

The working fluid in heat source flow circuit **1700** is motivated by hsfc fluid transfer device **1720** (optional, not required if utilizing gravity-induced circulation), filtered by hsfc fluid filtering device **1730** (optional), and its flow is controlled by hsfc hsfc-sfc evaporative heat transfer device working fluid discharge temperature regulating device **1795**. This last element acts to increase the flow of hsfc working fluid **1710** in heat source flow circuit **1700** when hsfc hsfc-sfc evaporative heat transfer device **1790** discharge temperature decreases below the desired operating point, conversely it acts to decrease hsfc working fluid **1710** flow when the discharge temperature rises above the desired operating point (the desired operating point is user adjustable).

The remaining enumerated subcomponents of heat source flow circuit **1700** serve to protect the circuit itself from the hydraulic hazards associated with fluids in confined spaces (i.e., thermal expansion, and over pressurization), as well as providing a way to add or remove working fluid to the circuit.

Heat recovery flow circuit **1600** (optional, omit if **1780** is not utilized) performs four essential functions in the operation of waste heat recycling thermal power plant **1000**. First, it receives recyclable heat from the heat liberating machinery units (e.g., gearbox, electric generator, electric motor(s), etc.) in hrfc machinery space **1630**. Second, it receives recyclable heat lost from hotter portions of the system [i.e., system heat lost to the surrounding environment by hms exposed surfaces **1630-20** (i.e., floor, walls, ceiling, equipment, piping, etc.), in this case the heat is "lost" to hrfc machinery space **1630**]. Note: heat lost by hrfc machinery space **1630** to the environment is non-

recoverable; however, this loss may be minimized and/or partially offset by passive solar gain during the warmest portions of the year. Third, it transports this recycled heat to hsfc hrfc-hsfc heat recycling condensing heat transfer device **1780** (optional) via hrfc heat recycling heat transfer device **1650**. Fourth, it provides "chilled" working fluid to hcdd working fluid inlet **1640-20**.

The working fluid in heat recovery flow circuit **1600** is motivated by gravity-induced circulation; further, this circulation is augmented with hrfc ventilation motive device **1620**, and the flow of hrfc working fluid **1610** is controlled by the operation of the previous element. Hrfc ventilation device **1620** is operated at maximum output to increase the flow of hrfc working fluid **1610** in order to reduce the temperature in hrfc machinery space **1630**, minimum output is utilized to decrease the flow and increase the temperature to the desired level, intermediate output levels are utilized to maintain the temperature at the desired level, once that temperature is attained.

As heated gas tends to rise, hcdd working fluid inlet **1640-20** is located near the ceiling of hrfc machinery space **1630** from there hms working fluid **1640-10** is conducted via hms cooling distribution device **1640** [optional, containing individual: hcdd distribution device **1640-30(x)** ("x" – designation changes for each unit) conducts hms working fluid **1640-10** to hcdd cooled machinery unit **1640-40(x)** ("x" – designation changes for each unit) where it receives recyclable heat liberated by the operation of the cooled machinery unit, next hcdd machinery cooling exhaust collection device **1640-50(x)** ("x" – designation changes for each unit) conducts the heated hms working fluid **1640-10** via chimney effect to hrfc heat recycling heat transfer device **1650**]. The heat conducted to hrfc heat recycling device **1650** is transported to hsfc hrfc-hsfc heat

recycling condensing heat transfer device **1780** (optional) via hhrhtd evaporative heat transfer device **1650-20**. Note: were a single operating point possible, this interconnection could be achieved more efficiently with a liquid-to-liquid heat transfer device; however, that type of operating environment is unlikely, and this evaporative/condensing interface provides a self-adjusting heat transfer device (i.e., the evaporative temperature will rise/fall on its own until the rate of evaporation is equal to the rate of condensation, and a new heat transfer equilibrium is established).

In addition, hrfc machinery space **1630** is protected from over pressurization damage by hms overpressure relief device **1630-30** (discharges to the environment), such damage is possible in the event of a catastrophic loss of working fluid containment and the resultant flashing of the working fluid to vapor, although the working fluid temperatures and pressures envisioned make this an extremely remote possibility.

Suction flow circuit **1200** performs seven essential functions in the operation of waste heat recycling thermal power plant **1000**. First, it provides recyclable heat to heat source flow circuit **1700** via sfc sfc-hsfc heat recycling heat transfer device **1230**. Second, it utilizes residual sfc working fluid **1210** pressure to operate sfc shrd-ssths fluid transfer device **1240**, this element draws excess working fluid from shrd shrd-hsfc evaporative heat transfer device **1280-20** and along with sfc working fluid **1210** combines to provide vigorous circulation within the heat transfer passages of sfc sub-ambient temperature heat sink **1250** and sfc heat replenishment device **1280**. Third, it receives recyclable heat (i.e., waste heat in a typical heat engine) from sfc sub-ambient temperature heat sink **1250**, this occurs specifically in ssths ihefc-sfc evaporative heat transfer device **1250-20**, where most of ssths working fluid **1250-10** admitted is

converted to vapor. The portion of ssths working fluid **1250-10** that remains in liquid form is transported to sfc heat replenishment device **1280** via shrd hsfc-sfc evaporative heat transfer device ssths liquid supply device **1270**. The portion of ssths working fluid **1250-10** that is converted to vapor is transported to sfc heat replenishment device **1280** via ssths liquid/vapor separation device **1250-30** (optional), ssths ihefc-sfc evaporative heat transfer device pressure regulating device **1250-40**, and shrd hsfc-sfc evaporative heat transfer device ssths vapor supply device **1260**. Fourth, it receives make-up heat (i.e., replacing the heat converted to work or lost from the system) from heat source flow circuit **1700** via shrd hsfc-sfc evaporative heat transfer device **1280-20** and shrd hsfc-sfc super heat heat transfer device **1280-40** (optional). Fifth, it transports this super heated vapor to cfc sub-ambient pressure generating device **1320** via shrd liquid/vapor separation device **1280-30** (optional), shrd hsfc-sfc super heat heat transfer device **1280-40** (optional), and shrd hsfc-sfc evaporative heat transfer device pressure regulating device **1280-50**. Sixth, it provides the heat (i.e., latent heat of vaporization and super heat contained within the super heated vapor) required to increase the temperature of mfc working fluid **1110** to that observed at the discharge of cfc sub-ambient pressure generating device **1320**. Seventh, it provides working fluid to conjoined flow circuit **1300**.

Sfc working fluid **1310** flow is motivated by the pressure differential between cfd flow separation chamber **1340-30** and cspgd suction chamber **1320-40**, and its flow is controlled by sfc fluid flow regulating device **1220**. Note: by producing a low-pressure region, cfc sub-ambient pressure generating device **1320** enables the pressure regulating devices (**1250-40** & **1280-50**) to regulate the pressure of their respective evaporative heat

transfer devices (**1250-20** & **1280-20**) by controlling the flow of working fluid vapor flow that exits their respective evaporative heat transfer device. This has an added benefit to the operation of waste heat recycling thermal power plant **1000**; precision regulation of these evaporating pressures also produces precise control of the temperatures within the respective evaporative heat transfer device (**1250-20** & **1280-20**).

Motive flow circuit **1100** performs four essential functions in the operation of waste heat recycling thermal power plant **1000**. First, it produces the pressure differential that is responsible for motivating all working fluid flow in motive flow circuit **1100**, suction flow circuit **1200**, and conjoined flow circuit **1300**. Second, it filters (if so configured) all the working fluids in those same circuits. Third, it provides the high-pressure working fluid to cfc sub-ambient pressure generating device **1320** that is required to generate a low-pressure region in cspgd suction chamber **1320-40**. Fourth, it provides working fluid to conjoined flow circuit **1300**.

Mfc working fluid **1110** is motivated by mfc fluid transfer device **1120**, and is filtered by mfc fluid filtering device **1130** (optional), and its flow is controlled by mfc fluid flow regulating device **1140**. The previous element acts to decrease mfc working fluid **1110** flow, when the flow exceeds the desired operating point, and conversely it acts to increase the flow, when it is below the desired operating point (the desired operating point is user adjustable).

Conjoined flow circuit **1300** performs four essential functions in the operation of waste heat recycling thermal power plant **1000**. First, it receives high-pressure liquid from motive flow circuit **1100** and super heated vapor from suction flow circuit **1200**, and combines these flows to produce the high temperature working fluid liquid flow

discharged from cfc sub-ambient pressure generating device **1320**. Second, it transports this thermal energy-rich working fluid liquid flow to cfc super-ambient temperature heat source **1330** where it gives up heat to ihefc super-ambient temperature heat source **1430**. Third, it provides working fluid to motive flow circuit **1100** and suction flow circuit **1200**. Fourth, via cssd thermal expansion device **1350-20** it is possible to adjust the "ambient" pressure experienced at cfd flow separation chamber **1340-30**.

Cfc working fluid **1310** flow is motivated by the pressure differential between cfc sub-ambient pressure generating device **1320** discharge and cfd flow separation chamber **1340-30**, and is controlled by the resistance to flow inherent in the same circuit (i.e., depending upon configuration, multiple heat transfer devices impede the flow of the working fluid). Note: the pressure differential generated between **1320-50** & **1340-30** will rise/fall on its own until the rate at which working fluid leaves the conjoined flow circuit **1300** is equal to the rate at which working fluid enters the same circuit, thus establishing a new mass transfer equilibrium.

Cssd overpressure relief device **1350-30** is interposed between cfd flow separation chamber **1340-30** and ssftd cssd overpressure relief device working fluid inlet **1240-30**, in the event of an overpressure condition this element would allow excess working fluid to be routed to ssths ihefc-sfc evaporative heat transfer device **1250-20**, which has a surge capacity. Cssd venting/servicing port **1350-40** allows for adding or removing working fluid from conjoined flow circuit **1300**.

Incorporated heat engine flow circuit **1400** performs six essential functions in the operation of waste heat recycling thermal power plant **1000**. First, it receives heat from conjoined flow circuit **1300** via ihefc super-ambient temperature heat source **1430**.

Second, it transports this heat to ihefc pressure expansion device **1460** via ihefc fluid flow regulating device **1450**. Third, it produces mechanical power by pressure expanding ihefc working fluid **1410** in ihefc pressure expansion device **1460** (e.g., Rankine cycle vapor turbine). Fourth, it rejects recyclable heat to suction flow circuit **1200** via ihefc sub-ambient temperature heat sink **1470**. Fifth, it provides a hermetic circuit to lubricate ihefc pressure expansion device **1460** via ihefc pressure expansion device lubricating circuit **1480** (optional). Sixth, it provides working fluid to ihefc super-ambient heat source **1430** [this function can be accomplished utilizing gravity-induced circulation, augmented with or supplanted by, ihefc fluid transfer device **1420** (optional)].

The remaining enumerated subcomponents of incorporated heat engine flow circuit **1400** serve to protect the circuit itself from the hydraulic hazards associated with fluids in confined spaces (i.e., thermal expansion, and over pressurization), as well as providing a device to add or remove working fluid to the circuit.

Mechanical output device **1500** performs four essential functions in the operation of waste heat recycling thermal power plant **1000**. First, it receives the mechanical power produced by ihefc pressure expansion device **1460**. Second, it transmits this mechanical power to hrfc machinery space **1630** via mod hermetic power coupling **1510A** or mod intermediate drive shaft with shaft sealing device **1510B**. Third, it provides mechanical power to mod driven mechanical output device **1520** (e.g., gearbox, generator, propeller shaft, etc.). Fourth, it provides recyclable heat to heat recovery flow circuit **1600** via hrfc heat recycling heat transfer device **1650**.

To review, the operation of waste heat recycling thermal power plant **1000**, requires heat source flow circuit **1700** to acquire and transport heat in sufficient quantity

to replace all of the heat that is converted to work or lost from the system. This heat is then transferred to suction flow circuit **1200** where it completes the evaporation of sfc working fluid **1210** flow, and super heats the entire shrd hsfc-sfc evaporative heat transfer device pressure regulating device **1280-50** inlet flow (i.e., all of the liquid provided to suction flow circuit **1200** from conjoined flow circuit **1300** is returned to conjoined flow circuit **1300** from suction flow circuit **1200** in the form of super heated vapor). This super heated vapor then combines with liquid from motive flow circuit **1100** in cfc sub-ambient pressure generating device **1320** to produce a thermal energy-rich working fluid liquid flow which is provided to cfc super-ambient temperature heat source **1330**. This heat is then provided to ihefc flow circuit **1400** where a portion of it is converted to mechanical power by ihefc pressure expansion device **1460**. This mechanical power is then transmitted via mechanical output device **1500** to mod driven mechanical device **1520** (e.g., gearbox, generator, propeller shaft, etc.) to drive a mechanical load. Wherever feasible, waste heat recycling thermal power plant **1000**, captures and reuses significant portions of the waste heat that its own operation liberates, in particular the heat rejected to sfc sub-ambient temperature heat sink **1250** by incorporated heat engine flow circuit **1400**, thus lowering its net energy utilization per unit of mechanical power produced.

3. Alternative Embodiments - Physical Layout & Operation

The basic embodiment of the waste heat recycling thermal power plant **1000** is similar to the main embodiment, the differences being that none of the optional components installed in the main embodiment are utilized in the basic embodiment. The

operation of the basic embodiment is also similar to that of the main embodiment; however, the functions performed by the optional components installed in the main embodiment are not performed at all, or not performed as well in the basic embodiment.

One alternative embodiment of the waste heat recycling thermal power plant **1000** utilizes a reconfigured suction flow circuit (Fig 2). This approach combines most of the functions that are performed by the sfc sub-ambient temperature heat sink **1250** and the sfc heat replenishment device **1280** of the main embodiment into a single device. Further, it eliminates one evaporation process and the need for a device to control that process' evaporation pressure. The operation of the alternative embodiment is also similar to that of the main embodiment; however, its reconfigured suction flow circuit can produce a colder heat sink temperature than that of the main embodiment. This alternative embodiment has much to recommend its adoption over the main embodiment, but at this time, we have more experience with and understanding of the main embodiment.

Other alternative embodiments involve: rerouting the flow of the ihefc fluid flow regulating device **1450** discharge to acquire additional super heat by cooling the mod driven mechanical device **1520**, or rerouting the mfc fluid flow regulating device **1140** discharge to acquire additional sensible heat by cooling the mod driven mechanical device **1520**, and still others involve various methods for evaporating the working fluid and/or the use of various combinations of working fluids.

4. Conclusion, Ramifications, and Scope

Accordingly, the reader will see that the waste heat recycling thermal power plant **1000** of this invention can be used to convert the heat contained in a thermal reservoir or a thermal stream to mechanical power, and thereby drive a mechanical load. In addition, the waste heat recycling that occurs within the invention itself enables the waste heat recycling thermal power plant **1000** to operate at "high" net thermal efficiencies, even while extracting replenishment heat from "low-temperature" external heat sources. Furthermore, the waste heat recycling thermal power plant **1000** has these additional advantages in that

* it permits the production of mechanical power without burning hydrocarbon-based fuel, thus eliminating the attendant release of "greenhouse" gases;

* it permits the production of mechanical power with minimal modifications and/or adaption expenses to a "host" facility;

* it permits the production of mechanical power reliably, through its utilization of robust sub-components;

* it permits the production of mechanical power without the need to purchase additional fuel, thus improving the fuel efficiency of the "host" facility;

* it permits the production of mechanical power by extracting replenishment heat directly from the environment.

Although the description above contains many specificities, these should not be construed as limiting the scope of the invention but merely providing illustrations of some of the presently preferred embodiments of this invention. For example, the external heat source can take many forms, such as: an industrial process' cooling fluid, a

geothermal pool, a solar collector, an internal combustion engine's coolant and/or its exhaust, a sufficiently large body of liquid water (e.g., a lake, or an ocean), etc.

Thus the scope of the invention should be determined by the appended claims and their legal equivalents, rather than by the examples given.